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Attorney Docket No. 0819-255
First Inventor or Application Identifier: Hiroshige HIRANO et al.
Title: FERROELECTRIC MEMORY DEVICE
Express Mail Label No.

APPLICATION ELEMENTS
See MPEP chapter 600 concerning utility patent application contents.

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1. ☒ Fee Transmittal Form (e.g., PTO/SB/17)
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(preferred arrangement set forth below)
 - Descriptive title of the invention
 - Cross References to Related Applications
 - Statement Regarding Fed sponsored R & D
 - Reference to Microfiche Appendix
 - Background of the invention
 - Brief Summary of the invention
 - Brief Description of the Drawings (if filed)
 - Detailed Description
 - Claim(s)
 - Abstract of the Disclosure
3. ☒ Drawing(s) (35 USC 113) Total Sheets [5]
4. ☒ Oath or Declaration Total Pages [3]
 - a. ☒ Newly executed (original or copy)
 - b. ☐ Copy from a prior application (37 CFR 1.63(d))
(for continuation/divisional with Box 17 completed)
[Note Box 5 below]
 - i. ☐ DELETION OF INVENTOR(S)
Signed statement attached deleting
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The entire disclosure of the prior application, from which a
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6. ☐ Microfiche Computer Program (Appendix)
7. Nucleotide and/or Amino Acid Sequence Submission
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ACCOMPANYING APPLICATION PARTS

8. ☒ Assignment Papers (cover sheet & document(s))
9. ☐ 37 CFR 3.73(b) Statement [] Power of Attorney
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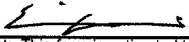
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FERROELECTRIC MEMORY DEVICE

BACKGROUND OF THE INVENTION

The present invention relates to a ferroelectric memory device, and more particularly relates to measures taken to improve the reliability thereof.

Over the past few years, portable communications terminals, IC cards and the like have been rapidly popularized around the world. To operate these types of electronic units more efficiently, nonvolatile semiconductor memory devices for use in these units are increasingly required to operate at an even lower voltage and at an even higher speed while consuming even lower power. A ferroelectric memory device is one of strong candidate nonvolatile memory devices that are expected to fulfill these requirements at the same time. A device of this type includes a ferroelectric capacitor, in which a ferroelectric film is sandwiched between a pair of electrodes. Data can be stored thereon in a nonvolatile manner depending on whether the ferroelectric material within the capacitor is polarized in one direction or the other, which is reversed by the application of a positive or negative electric field. In rewriting data stored on a ferroelectric memory device, such an electric field as reversing the direction of polarization in the ferroelectric film has only to be applied. Accordingly, the ferroelectric memory

device can advantageously contribute to higher-speed operation with lower voltage applied and lower power dissipated.

Figure 4 is a plan view of an array of memory cells in a conventional ferroelectric memory device as viewed from above its layer in which bit lines are formed. Figure 5 is a vertical cross-sectional view of part of the array taken along the line V-V in Figure 4.

As shown in Figure 5, an active region OD is formed to be surrounded by a LOCOS film 52 on an Si substrate 51. Within this active region OD, source/drain doped layers 53, and polysilicon gates 54 are formed. A first interlevel dielectric film 55 is formed over the Si substrate 51. Memory cell capacitors are formed at respective regions over the LOCOS film 52 on the first interlevel dielectric film 55. Each of these memory cell capacitors includes: a bottom electrode 56 made of a metal such as platinum or iridium; a ferroelectric film 57 made of a ferroelectric material; and a top electrode 58 also made of a metal such as platinum or iridium. A second interlevel dielectric film 59 is formed over the first interlevel dielectric film 55. And storage lines 60, made of aluminum containing copper, are formed on the second interlevel dielectric film 59.

In Figure 4, the gates 54 and bottom electrodes 56 extend along the rows of the array as word lines WL0, WL1, WL2 and WL3 and cell plate lines CP0, CP1, CP2 and CP3, respec-

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tively. A group of bit lines **BL0**, **/BL0**, **BL1**, **/BL1**, **DBL** and **/DBL** are formed to extend along the columns of the array. One of these bit lines, i.e., a bit line **DBL**, is illustrated in Figure 5 by a phantom line. Each top electrode **58** shown in Figure 5 corresponds to a data storage node of a DRAM, and is identified by **TE** in Figure 4. Each storage line **60** is connected to an associated top electrode **58** via a contact **CE** and to an associated doped layer **53** of the memory cell transistor via a contact **CW1**. Each bit line **BL0**, **/BL0**, **BL1**, **/BL1**, **DBL** or **/DBL** is connected to an associated doped layer **53** via a contact **CW2**. And the respective storage lines **60** and the group of bit lines **BL0**, **/BL0**, **BL1**, **/BL1**, **DBL** and **/DBL** constitute a first interconnection layer.

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In this device, data can be retained as either "0" or "1" by holding a ferroelectric film **57** in either positively or negatively polarized state depending on a level difference between a voltage on a bit line supplied via an associated doped layer **53** and a voltage on an associated cell plate line.

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The reliability of this ferroelectric memory device sometimes deteriorates due to the infant mortality failure of the ferroelectric capacitor or degradation in retention characteristics thereof. The present inventors carried out intensive research to find out measures to be taken for solving this problem. As a result of experiments, we obtained data

suggesting that the decrease in reliability might have been brought about probably because a storage line 60 exists over an excessively wide range above an associated top electrode 58 of a ferroelectric capacitor.

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SUMMARY OF THE INVENTION

An object of the present invention is providing a ferroelectric memory device with improved reliability, in which the deterioration in characteristics of a ferroelectric capacitor can be eliminated by controlling an overlap area between a storage line and an underlying top electrode in a planar layout.

To achieve this object, the present invention adopts a structure in which a first interconnection layer does not cover at least one side of each top electrode of a memory cell in the planar layout thereof.

A ferroelectric memory device according to the present invention includes a ferroelectric capacitor including a top electrode having a rectangular planar pattern, a bottom electrode, and a ferroelectric film interposed between the top and bottom electrodes. The memory device further includes a memory cell transistor including first and second doped layers and a gate. The memory cell transistor is used for controlling a voltage supplied to the top electrode of the ferroelectric capacitor. The memory device further includes: an

interlevel dielectric film formed over the memory cell transistor and the ferroelectric capacitor; and a first interconnection layer formed on the interlevel dielectric film. In the planar layout of the memory device, the first interconnection layer partially overlaps with the top electrode of the ferroelectric capacitor, and does not cover at least one side of the rectangular top electrode.

In this structure, a stress applied by the first interconnection layer to the ferroelectric capacitor or a leakage current flowing between adjacent portions of the first interconnection layer decreases, thus preventing decrease in early yield resulting from leakage failure and deterioration in retention characteristics. As a result, the reliability of the ferroelectric memory device can be improved.

In one embodiment of the present invention, the first interconnection layer includes a storage line and a bit line. The storage line is connected to the top electrode of the ferroelectric capacitor and to the first doped layer of the memory cell transistor, and is linear in the planar pattern thereof. The bit line is connected to the second doped layer of the memory cell transistor. In this particular embodiment, the storage line may intersect only one side of the top electrode of the ferroelectric capacitor in the planar layout. Alternatively or additionally, the bit line may not overlap with the top electrode of the ferroelectric capacitor

in the planar layout.

In another embodiment of the present invention, the storage line may include: a first region connected to the top electrode of the ferroelectric capacitor; a second region
5 connected to the first doped layer of the memory cell transistor; and a third region interposed between the first and second regions. The third region may intersect the side of the top electrode in the planar layout. The line width of the third region is preferably smaller than that of the first
10 and second regions.

In such an embodiment, remarkable effects can be attained in respect of the stress reduction and so on.

In still another embodiment, the first interconnection layer is preferably made of a material containing at least
15 one of aluminum and copper.

In still another embodiment, the ferroelectric memory device may further include: an upper interlevel dielectric film formed to cover the first interconnection layer; and a second interconnection layer formed on the upper interlevel
20 dielectric film. The second interconnection layer may totally cover the top electrode of the ferroelectric capacitor in the planar layout.

In still another embodiment, the ferroelectric memory device may further include: an upper interlevel dielectric
25 film formed to cover the first interconnection layer; and a

second interconnection layer formed on the upper interlevel dielectric film. The second interconnection layer may totally cover the bottom electrode of the ferroelectric capacitor in the planar layout.

5 In these embodiments, it is possible to prevent the characteristics of the ferroelectric capacitor from being deteriorated due to annealing conducted before the second interconnection layer is formed. In addition, the stress applied to the ferroelectric capacitor during the formation
10 of the second interconnection layer can be relaxed.

In still another embodiment, the second interconnection layer is also preferably made of a material containing at least one of aluminum and copper.

15 BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a plan view of a ferroelectric memory device according to a first embodiment of the present invention as viewed from above a first interconnection layer thereof.

Figure 2 is a cross-sectional view of the device taken
20 along the line II-II in Figure 1.

Figure 3 is a plan view of a ferroelectric memory device according to a second embodiment of the present invention as viewed from above a first interconnection layer thereof.

Figure 4 is a plan view of a conventional ferroelectric
25 memory device as viewed from above a first interconnection

layer thereof.

Figure 5 is a cross-sectional view of the device taken along the line V-V in Figure 4.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

EMBODIMENT 1

Figure 1 is a plan view of an array of memory cells in a ferroelectric memory device according to a first embodiment of the present invention as viewed from above a layer in which bit lines are formed. Figure 2 is a vertical cross-sectional view of the device taken along the line II-II in Figure 1.

As shown in Figure 2, an active region OD is formed to be surrounded by a LOCOS film 12 on an Si substrate 11. Within this active region OD, source/drain doped layers 13 and polysilicon gates 14 are provided. A first interlevel dielectric film 15 is formed over the Si substrate 11. Memory cell capacitors are formed at respective regions over the LOCOS film 12 on the first interlevel dielectric film 15. Each of these memory cell capacitors includes: a bottom electrode 16 made of a metal such as platinum or iridium; a ferroelectric film 17 made of a ferroelectric material described later; and a top electrode 18 also made of a metal such as platinum or iridium. A second interlevel dielectric film 19 is formed over the first interlevel dielectric film 15. And

storage lines 20 made of aluminum containing copper are formed on the second interlevel dielectric film 19.

In Figure 1, the gates 14 and bottom electrodes 16 extend as word line WL0, WL1, WL2 and WL3 and cell plate lines CP0, CP1, CP2 and CP3, respectively, along the rows of the array. A group of bit lines BL0, /BL0, BL1, /BL1, DBL and /DBL are formed to extend along the columns of the array. One of these bit lines, i.e., a bit line DBL, is illustrated in Figure 2 by a phantom line. Each top electrode 18 shown in Figure 2 corresponds to a data storage node of a DRAM, and is identified by TE in Figure 1. Each storage line 20 is connected to an associated top electrode 18 via a contact CE and to an associated doped layer 13 of the memory cell transistor via a contact CW1. Each bit line BL0, /BL0, BL1, /BL1, DBL or /DBL is connected to an associated doped layer 13 via a contact CW2. And the respective storage lines 20 and the group of bit lines BL0, /BL0, BL1, /BL1, DBL and /DBL constitute a first interconnection layer.

In this device, data can be retained as either "0" or "1" by holding a ferroelectric film 17 in either positively or negatively polarized state depending on a level difference between a voltage on a bit line supplied via an associated doped layer 13 and a voltage on an associated cell plate line.

The ferroelectric memory device of the present invention

is characterized in that a storage line 20 overlaps with an associated top electrode (TE) 18 in a different planar area than that of the conventional structure. In the conventional ferroelectric memory device structure, the right end of each storage line 60 goes over an associated side of an underlying top electrode 58 to protrude outward as shown in Figure 5. In the plan view shown in Figure 4, each storage line 60 intersects two sides of an associated top electrode 58. In contrast, in the ferroelectric memory device of the present invention, the right end of each storage line 20 does not protrude outward from an associated side of an underlying top electrode 18 as shown in Figure 2. In the plan view shown in Figure 1, each storage line 20 intersects only one side of an associated top electrode 18. Furthermore, in the conventional structure shown in Figure 4, each bit line covers another two sides of an associated pair of top electrodes 58. On the other hand, according to the present invention, each bit line (e.g., BL1) is disposed not to overlap with any top electrode 20 in the planar layout of the device. In other words, as viewed from above, the first interconnection layer covers all of the four sides of each top electrode 60 in the conventional ferroelectric memory device shown in Figure 4. In contrast, the first interconnection layer does not cover at least one side of each top electrode 18 in the inventive ferroelectric memory device shown in Figure 1.

In a contact **CE** between a top electrode **18** and an associated storage line **20**, an overlap margin is defined at a minimum size according to a design rule in view of a mask-to-mask placement error between the contact **CE** and the storage
5 line **20**.

By reducing in this way the overlap area between a storage line **20** and an associated top electrode **18** as much as possible, the following effects are attained. Specifically, it is possible to prevent the early yield from decreasing due
10 to a leakage failure between a bit line and a storage line. In addition, the characteristics of the ferroelectric capacitor can be significantly improved in respect of data retention, in particular. This is because the polarizability of the ferroelectric capacitor can be improved. At present, these ef-
15 fects are attained probably because of the following reasons: decrease in stress applied by a storage line **20** to an associated ferroelectric capacitor; and/or reduction in leakage caused between a storage line **20** shorter in length and a neighboring bit line (e.g., **BL1**). Also, possibly, advantageous effects of a material for a third interlevel dielectric
20 film (not shown), which is formed over the storage lines **20**, on the ferroelectric capacitors might be promoted with such a configuration.

It should be noted, however, so long as each storage line
25 **20** covers only one side of an associated top electrode **18** (TE)

in the planar layout, an associated bit line may overlap with the top electrode 18. Alternatively, in the planar layout, if each bit line (e.g., BL1) does not overlap with an associated top electrode 18, then an associated storage line 20 may cover two sides of the top electrode 18. Nevertheless, according to the illustrated embodiment, the stress applied by the first interconnection layer to the top electrode 18 can be reduced more significantly than any other possible alternative exemplified above, resulting in marvelous improvement of the retention characteristics.

Also, in this embodiment, dummy bit lines DBL and /DBL are disposed at the far ends of the array of memory cells so as not to use the ferroelectric capacitors at those ends during the operation of the device. This is because even with the structure of this embodiment, the characteristics might not be improved otherwise. Specifically, although a memory cell located at an end of the array has the same structure as any other memory cell within the array, the former cell is adjacent to a region where no cells exist, and therefore exhibits a different characteristic than that of the latter cell.

If the ferroelectric memory device is fabricated to further include: a third interlevel dielectric film formed over the storage lines 20; and a second interconnection layer formed thereon (not shown), then that second interconnection

layer may cover the top or bottom electrodes 18 or 16. In such a case, it is possible to prevent the characteristics of a ferroelectric capacitor from being deteriorated due to annealing conducted before the second interconnection layer is formed. In addition, the stress applied to the ferroelectric capacitor during the formation of the second interconnection layer can be relaxed.

Particularly when the second interconnection layer is made of a material containing aluminum and/or copper, the following effects are attained. The second interconnection layer may be used as a backing layer for reducing the resistance of a word line (e.g., WL0, WL1) made of polysilicon and/or a cell plate line (e.g., CP0, CP1), which is the bottom electrode 16 of the ferroelectric capacitor. Since the resistance can be reduced, the ferroelectric memory device can operate at a higher speed. In addition, even if a word line is disconnected during a manufacturing process, electrical failures are less likely to happen, because the second interconnection layer, serving as a backing layer, are connected at numerous points.

EMBODIMENT 2

Figure 3 is a plan view of an array of memory cells according to a second embodiment of the present invention as viewed from above its layer in which bit lines are formed.

The ferroelectric memory device of the second embodiment is characterized in that the overlap area between each storage line 20 and an associated top electrode 18 (TE) is even smaller than that in the first embodiment. Specifically, as shown in Figure 3, each storage line 20 has such a planar shape that the line width of the central region thereof is smaller than that of the other regions thereof. The line width of the central region is defined at the minimum value according to a design rule for forming the storage line. In the other respects, the structure of the second embodiment is the same as that of the first embodiment.

In the ferroelectric memory device of the second embodiment, the overlap area between each storage line 20 and an associated top electrode 18 is further reduced as compared to the ferroelectric memory device of the first embodiment. Accordingly, the effects of the first embodiment can be attained more remarkably.

In the second embodiment, a second interconnection layer may also be formed over the storage lines 20 with a third interlevel dielectric film interposed therebetween as described in the first embodiment.

It should be noted, however, so long as each storage line 20 covers only one side of an associated top electrode 18 (TE) in the planar layout, an associated bit line may overlap with the top electrode 18. Alternatively, in the planar layout, if

each bit line (e.g., BL1) does not overlap with an associated top electrode 18, then an associated storage line 20 may cover two sides of the top electrode 18. Nevertheless, according to the illustrated embodiment, the stress applied by the first interconnection layer to the top electrode 18 can be reduced more significantly than any other possible alternative exemplified above, resulting in marvelous improvement of the retention characteristics.

In the foregoing embodiments, the ferroelectric film 17 may be made of a ferroelectric material selected from the group consisting of KNO_3 , $\text{PbLa}_2\text{O}_3\text{-ZrO}_2\text{-TiO}_2$ and $\text{PbTiO}_3\text{-PbZrO}_3$.

WHAT IS CLAIMED IS:

1. A ferroelectric memory device comprising:

a ferroelectric capacitor including a top electrode, a bottom electrode and a ferroelectric film interposed between the top and bottom electrodes, the top electrode having a rectangular planar pattern;

a memory cell transistor including first and second doped layers and a gate, the memory cell transistor controlling a voltage supplied to the top electrode of the ferroelectric capacitor;

an interlevel dielectric film formed over the memory cell transistor and the ferroelectric capacitor; and

a first interconnection layer formed on the interlevel dielectric film,

wherein, in a planar layout of the ferroelectric memory device, the first interconnection layer partially overlaps with the top electrode of the ferroelectric capacitor, and does not cover at least one side of the rectangular top electrode.

2. The device of Claim 1, wherein the first interconnection layer includes:

a storage line connected to the top electrode of the ferroelectric capacitor and to the first doped layer of the memory cell transistor, the storage line having a linear pla-

nar pattern; and

a bit line connected to the second doped layer of the memory cell transistor, and

wherein the storage line intersects only one side of the top electrode in the planar layout.

3. The device of Claim 2, wherein the storage line includes:

a first region connected to the top electrode of the ferroelectric capacitor;

a second region connected to the first doped layer of the memory cell transistor; and

a third region being interposed between the first and second regions and intersecting the side of the top electrode in the planar layout, and

wherein the line width of the third region is smaller than that of the first and second regions.

4. The device of Claim 2, wherein the bit line does not overlap with the top electrode in the planar layout.

5. The device of Claim 4, wherein the storage line includes:

a first region connected to the top electrode of the ferroelectric capacitor;

a second region connected to the first doped layer of the memory cell transistor; and

a third region being interposed between the first and second regions and intersecting the side of the top electrode in the planar layout, and

wherein the line width of the third region is smaller than that of the first and second regions.

6. The device of Claim 1, wherein the first interconnection layer includes:

a storage line connected to the top electrode of the ferroelectric capacitor and to the first doped layer of the memory cell transistor, the storage line having a linear planar pattern; and

a bit line connected to the second doped layer of the memory cell transistor, and

wherein the bit line does not overlap with the top electrode in the planar layout.

7. The device of Claim 1, wherein the first interconnection layer is made of a material containing at least one of aluminum and copper.

8. The device of Claim 1, further comprising:

an upper interlevel dielectric film formed to cover the

first interconnection layer; and

a second interconnection layer formed on the upper interlevel dielectric film,

wherein the second interconnection layer totally covers the top electrode of the ferroelectric capacitor in the planar layout.

9. The device of Claim 1, further comprising:

an upper interlevel dielectric film formed to cover the first interconnection layer; and

a second interconnection layer formed on the upper interlevel dielectric film,

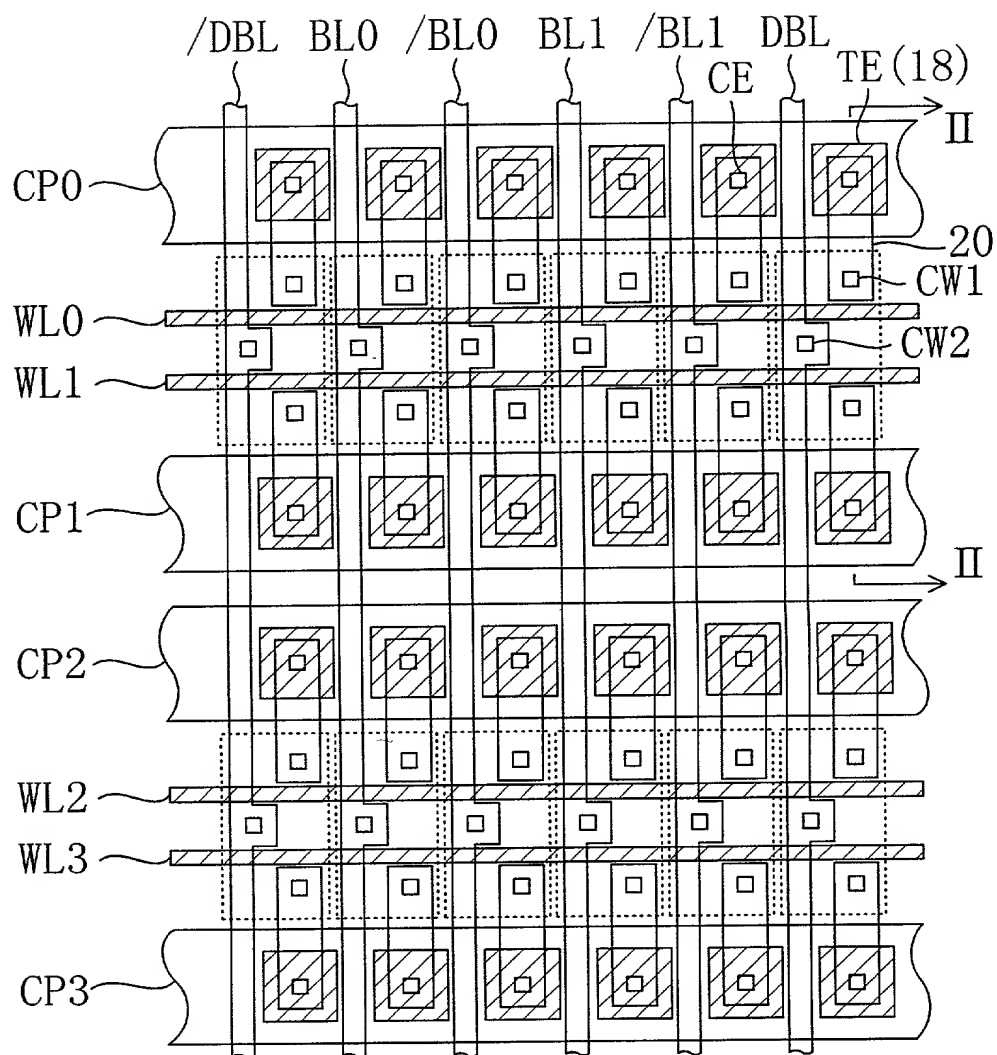
wherein the second interconnection layer totally covers the bottom electrode of the ferroelectric capacitor in the planar layout.

10. The device of Claim 9, wherein the second interconnection layer is made of a material containing at least one of aluminum and copper.

ABSTRACT OF THE DISCLOSURE

A memory cell transistor using a word line **WL** as the gate thereof is provided in an active region **OD**, and a ferroelectric capacitor, including bottom electrode, ferroelectric film and top electrode **TE**, is formed on a field oxide film. A first interconnection layer is made up of storage lines, each connecting the top electrode **TE** to one of doped layers of the memory cell transistor, and bit lines, each of which is connected to the other doped layer. In a planar layout, the storage line intersects only one side of the top electrode **TE** and the bit line **BL** does not overlap with the top electrode **TE**. Thus, it is possible to prevent the retention characteristics of the ferroelectric capacitor from being deteriorated due to the stress applied by the first interconnection layer to the ferroelectric capacitor. As a result, the reliability of a ferroelectric memory device, including, in a memory cell, a ferroelectric capacitor with a ferroelectric film interposed between the bottom and top electrodes, can be improved.

Fig. 1



Fi. 2

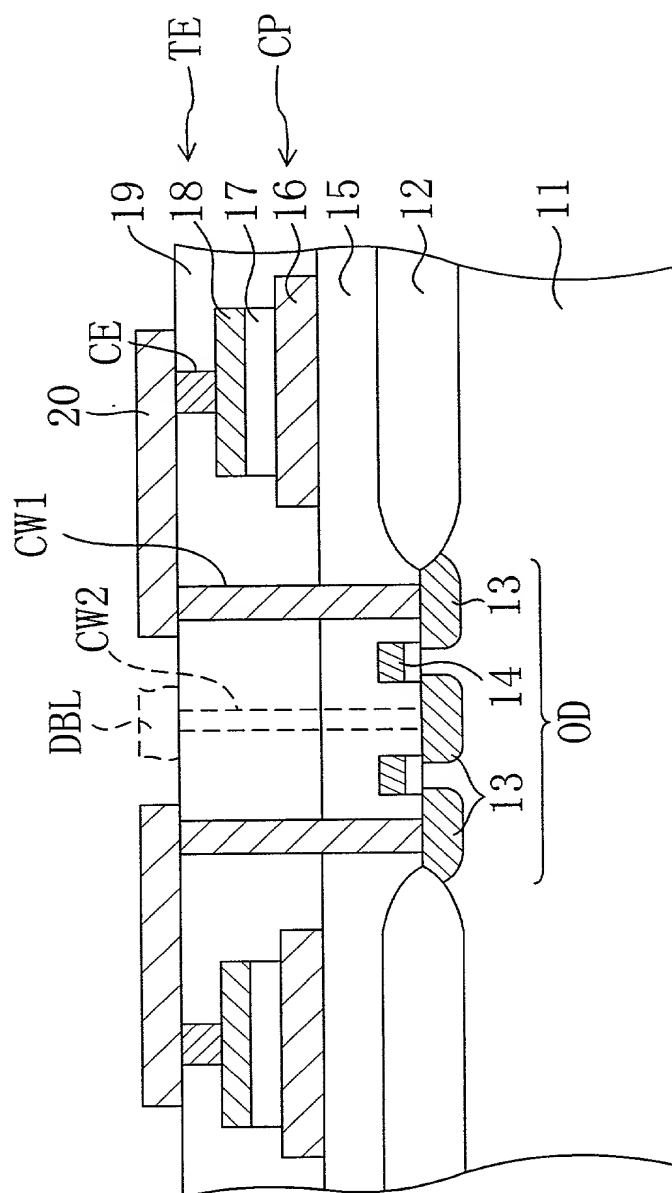


Fig. 3

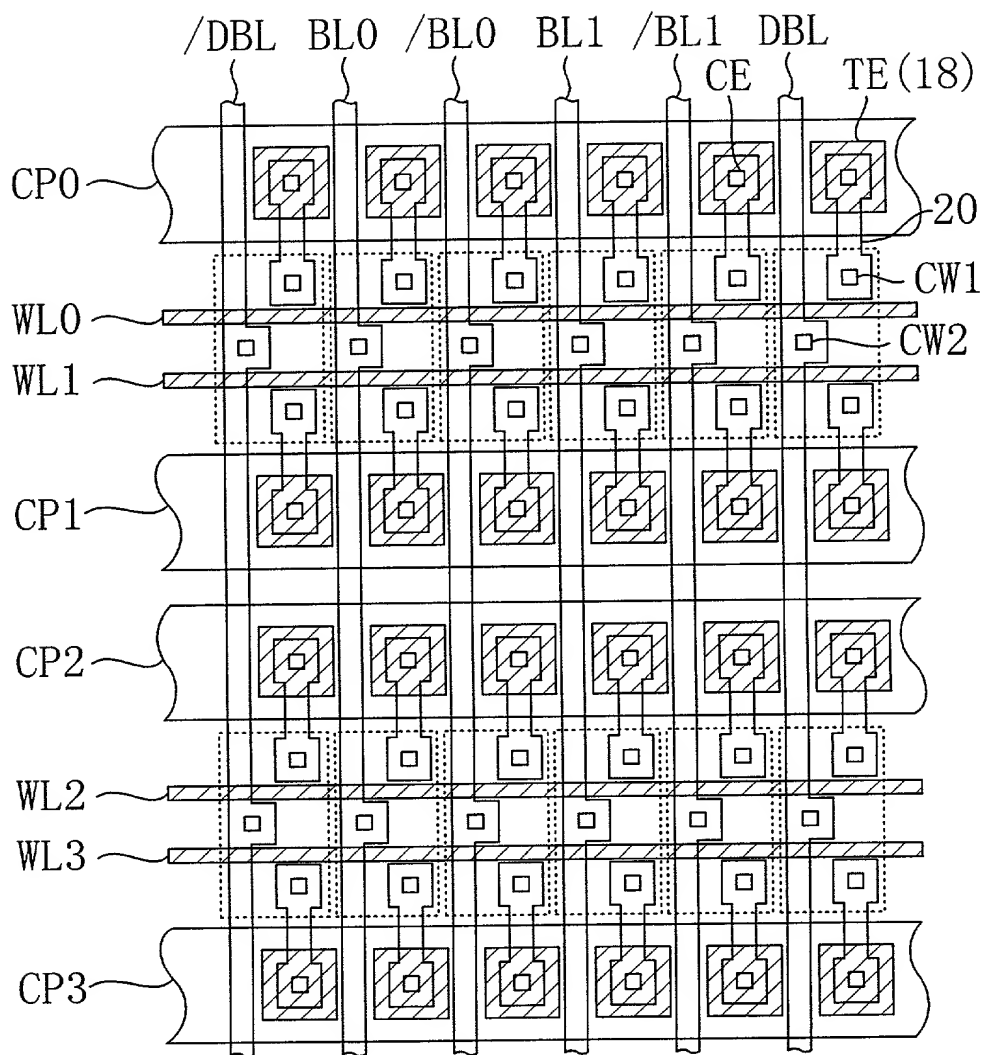
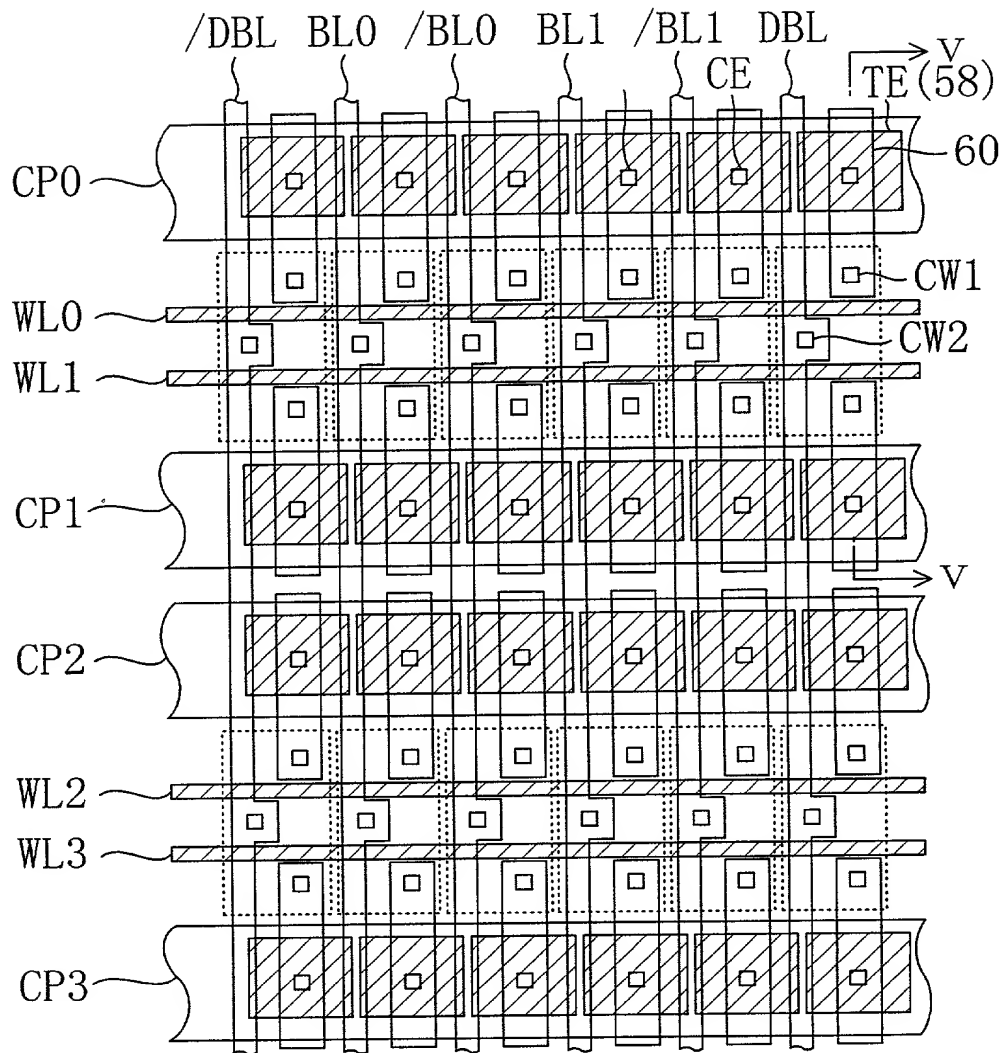


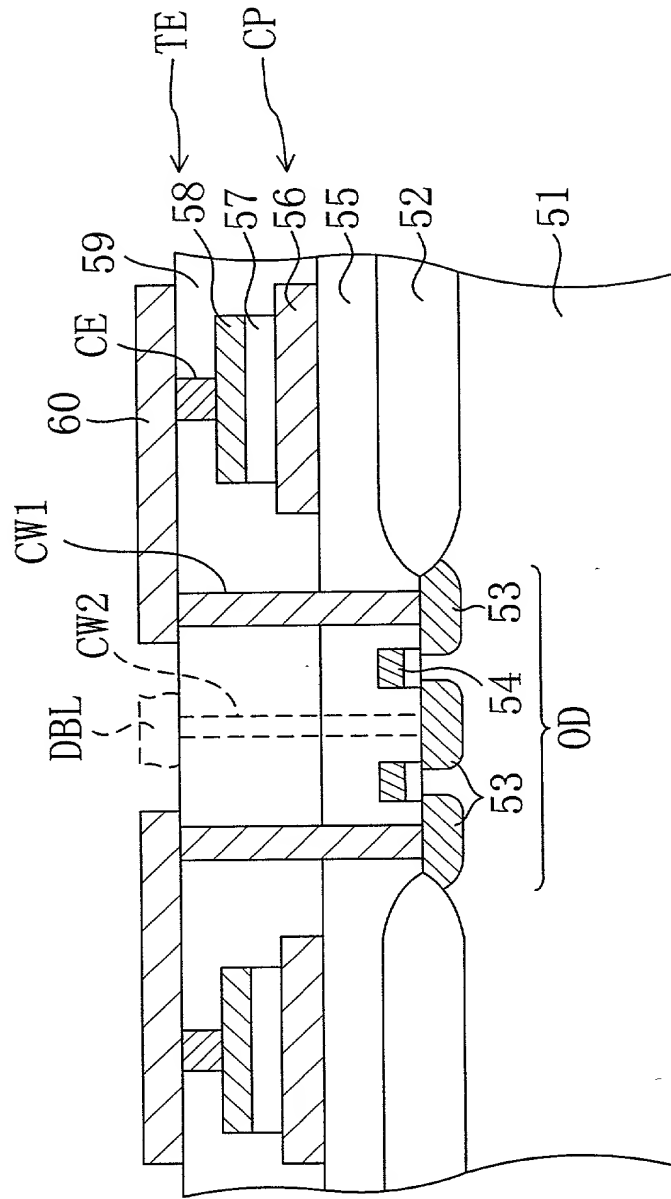
Fig. 4

PRIOR ART



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PRIOR ART



DECLARATION AND POWER OF ATTORNEY
FOR PATENT APPLICATION

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As a below named inventor, I hereby declare that: my residence, post office address and citizenship are as stated next to my name; that I verily believe that I am the original, first and sole inventor (if only one name is listed below) or a joint inventor (if plural inventors are named below) of the invention entitled: FERROELECTRIC MEMORY DEVICE, the specification of which is attached hereto unless the following box is checked:

☐ The specification was filed on _____
and was assigned Serial No. _____
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I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56.

I do not know and do not believe the same was ever known or used in the United States of America before my or our invention thereof, or patented or described in any printed publication in any country before my or our invention thereof, or more than one year prior to this application, that the same was not in public use or on sale in the United States of America more than one year prior to this application, that the invention has not been patented or made the subject of an inventor's certificate issued before the date of this application in any country foreign to the United States of America on an application filed by me or my legal representatives or assigns more than twelve months prior to this application, and that no application for patent or inventor's certificate on this invention has been filed in any country foreign to the United States of America prior to this application by me or my legal representatives or assigns, except as follows:

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Prior Foreign Application(s)			Priority Claimed	
(Number)	(Country)	(Month/Day/Year Filed)	Yes	No
10-167857	JAPAN	06/16/1998	X	

All foreign applications, if any, for any Patent or Inventor's Certificate filed more than 12 months prior to the filing date of this application:

Country	Application No.	Date of Filing (Month/Day/Year)

I hereby claim the benefit under Title 35, United States Code, §119(e) or §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56 which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

Application Serial No.	Filing Date	Status: patented, pending, abandoned

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

The undersigned hereby authorize any U.S. attorney or agent named herein to accept and follow instructions from MAEDA PATENT OFFICE as to any action to be taken in the Patent and Trademark Office regarding this application without direct communication between the U.S. attorney or agent and the undersigned. In the event of a change in the persons from whom instructions may be taken, the U.S. attorneys or agents named herein will be so notified by the undersigned.

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FULL NAME OF FOURTH JOINT INVENTOR (if any)	INVENTOR'S SIGNATURE	DATE
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FULL NAME OF FIFTH JOINT INVENTOR (if any)	INVENTOR'S SIGNATURE	DATE
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FULL NAME OF SIXTH JOINT INVENTOR (if any)	INVENTOR'S SIGNATURE	DATE
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FULL NAME OF SEVENTH JOINT INVENTOR (if any)	INVENTOR'S SIGNATURE	DATE
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FULL NAME OF EIGHTH JOINT INVENTOR (if any)	INVENTOR'S SIGNATURE	DATE
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